Reliability and Maintainability (R&M) Role in Designing for Safety and Affordability

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- History of Reliability and Maintainability
- Why Reliability Engineering
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The Paradigm Shift

- In the past, space vehicle designers focused on performance.
- Lessons learned from the Space Shuttle Program and other space systems showed the need to optimize launch vehicles for other system parameters besides performance (e.g. reliability, safety, cost, and availability).
- These lessons learned have forced a paradigm shift on how to design and build new launch vehicles.

History of R&M Engineering at NASA

1961

RELIABILITY OFFICE

Chief: HA SCHULZE
Dep. Chief: JW MOODY

OFFICE OF THE DIRECTOR

Director: W VON BRAUN
Dep. Dir /R&D: EFM REES

Other Departments

TECHNICAL SERVICES OFFICE

Chief: DH NEWBY
Dep. Chief: MI KENT
Safety Office Chief: LL ROBERTS

QUALITY DIVISION

Director: D GRAU
Dep Dir. R E GODREY

AEROBALLISTICS DIVISION

Director: ED GEISSLER
Dep. Director: RF HOELKER

History of R&M Engineering at NASA

Reliability engineering has played a key role in NASA mission success since the early Apollo days.



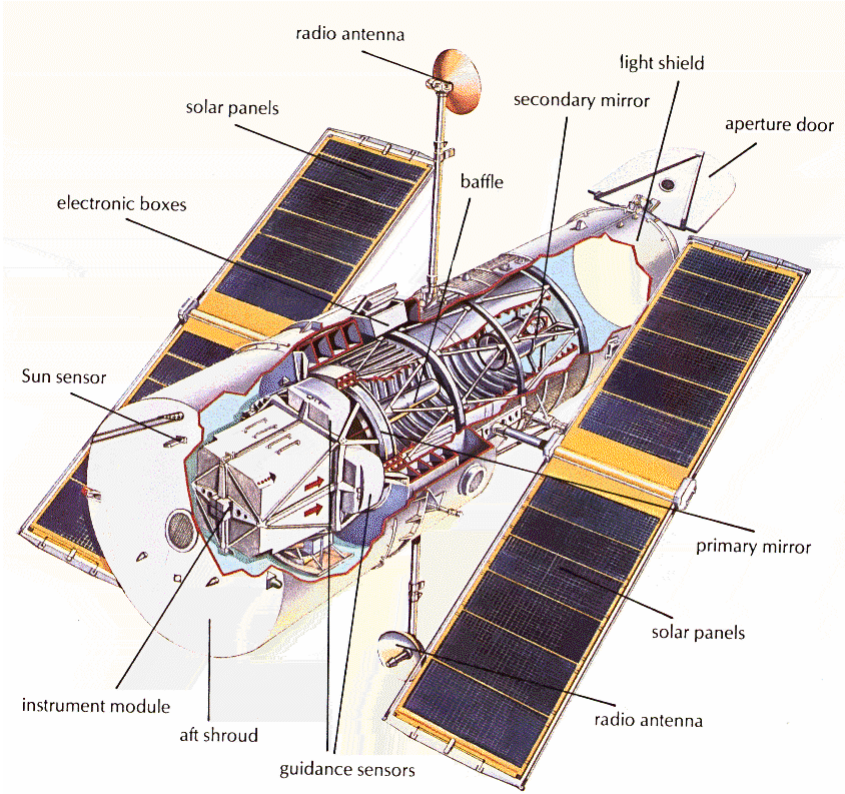


During the Apollo days, reliability engineers performed FMEA and Criticality analysis, prediction, and failure analysis.

History of R&M Engineering at NASA

Maintainability concepts were included early in the life cycle, where maintenance planning and optimum ORU usage in design saved the program significant costs when on-orbit repairs became necessary.





HST was designed with replaceable cameras and guidance sensors. Provisions were also made for change-out of limited life components (e.g. gyroscopes, batteries, and reaction wheels). Servicing missions were planned every three years using the Space Shuttle. In this way the initial expense of developing and launching the HST would be amortized over a longer lifetime while providing a consistent level of scientific return by incorporating the latest technologies.

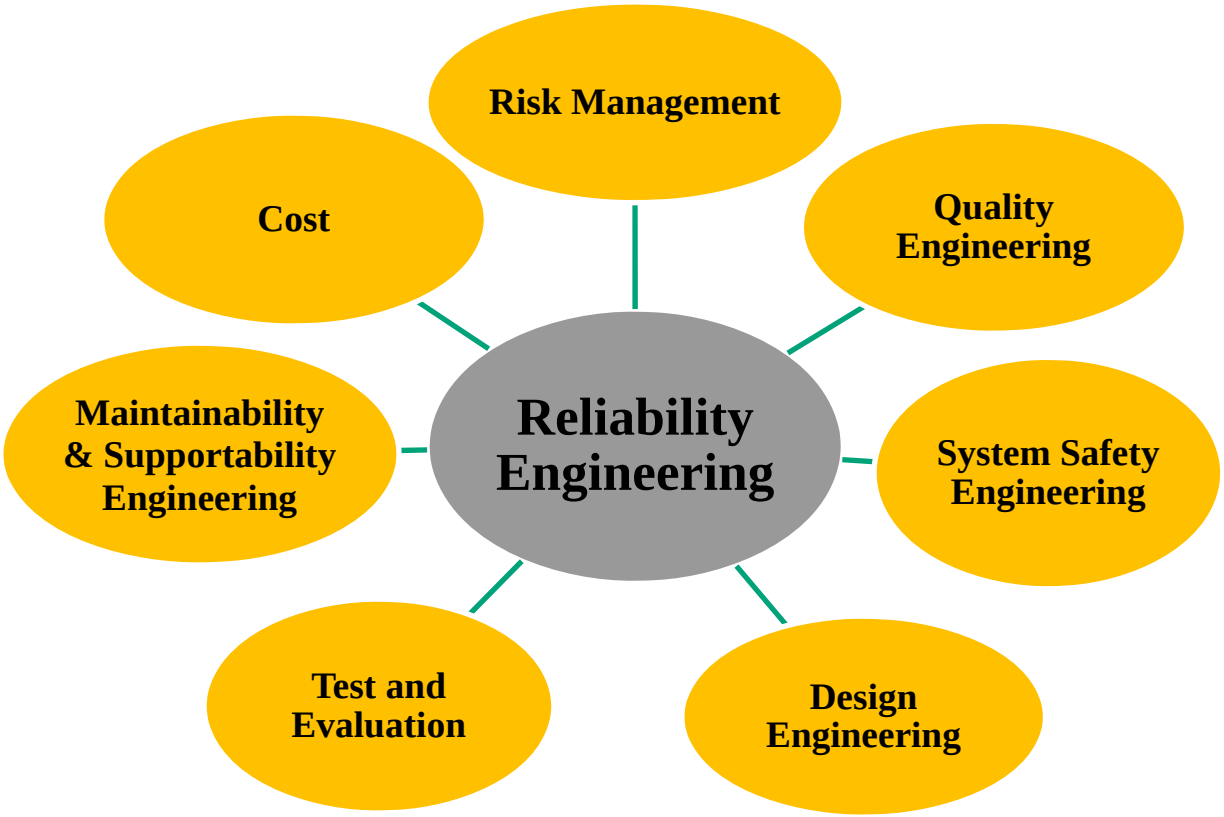
Why R&M Engineering?

- Reliability engineering has important interfaces with safety, quality, maintainability, supportability, cost, test, and design engineering.
- Reliability analysis is critical for understanding component failure mechanisms and integrated system failures, and identifying reliability critical design and process drivers.
- A comprehensive reliability program is critical for addressing the entire spectrum of engineering and programmatic concerns, from Loss of Mission (LOM) risk and the Loss of Crew (LOC) risk to sustainment and system life cycle costs.

Why Reliability Engineering?
Major Interfaces

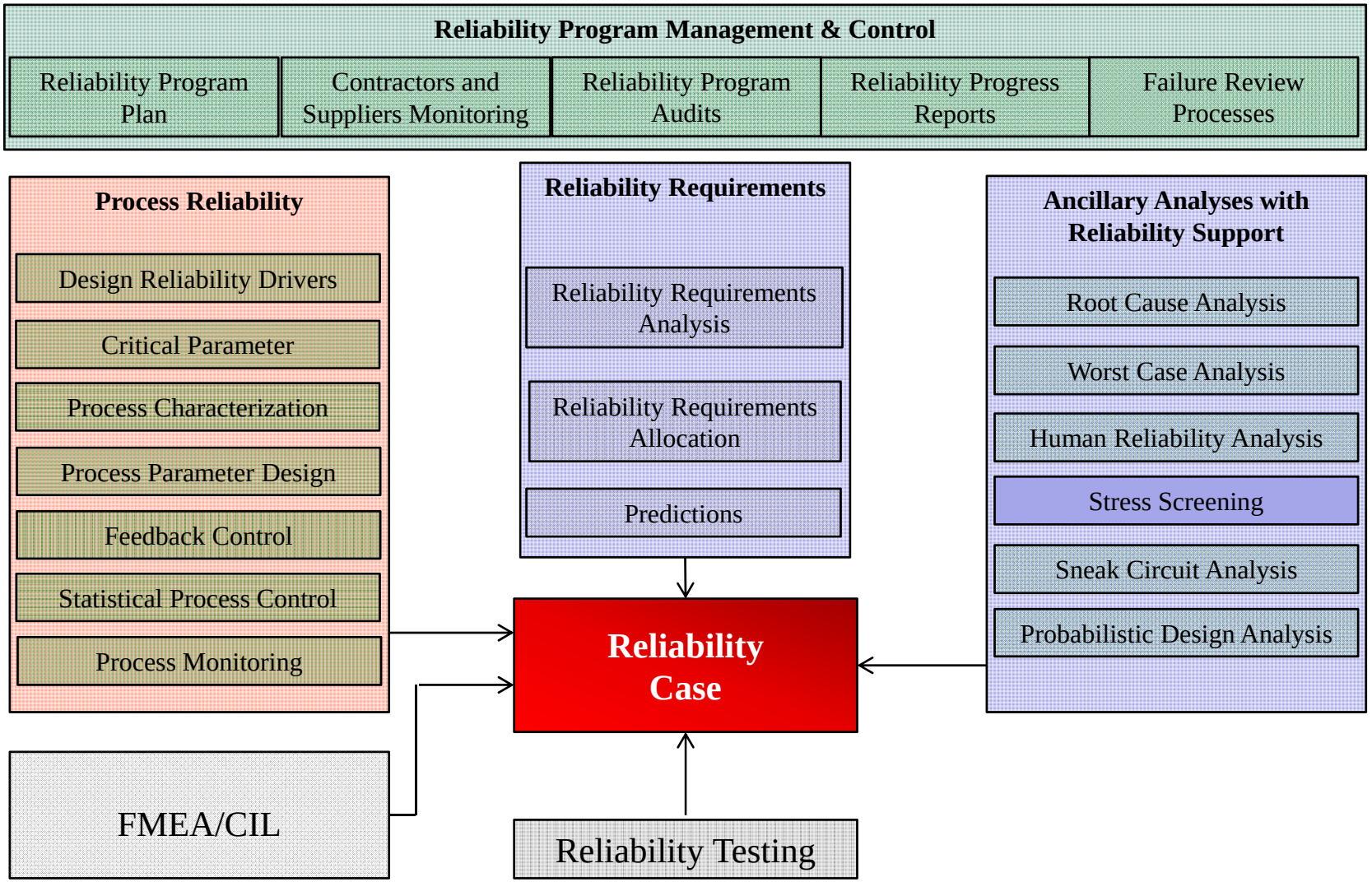
Reliability engineering has important interfaces with most engineering disciplines.

Reliability engineering as a discipline is: The application of engineering principles to the design and processing of products, both hardware and software, for the purpose of meeting product reliability requirements or goals.



Reliability as a figure of merit is: The probability that a product performs its intended function for a specified mission profile.

The Reliability Engineering Case



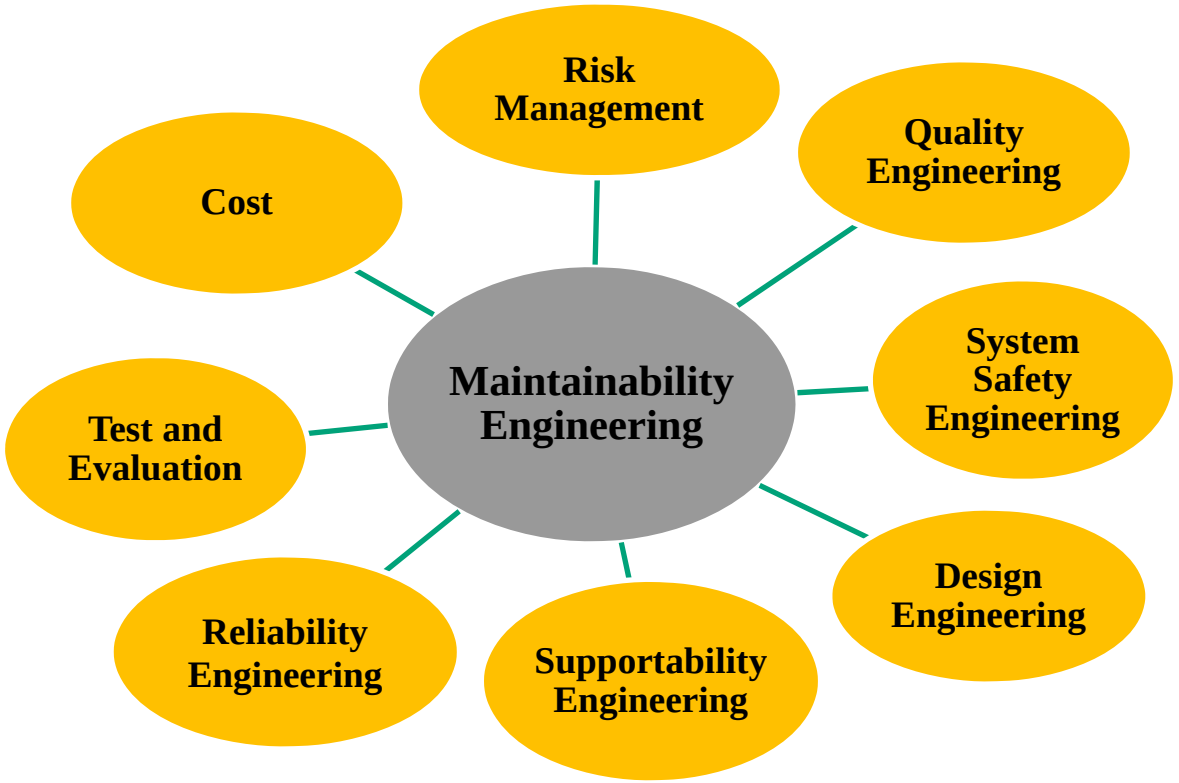
Why Maintainability Engineering?

- Maintainability engineering has important interfaces with reliability engineering, design engineering, maintenance planning, supportability engineering, and logistic support.
- Maintainability analysis is critical for identifying the design features and characteristics needed for time efficient processing, preventive and corrective maintenance, rapid fault detection and diagnosis, and retest/repair validation.
- A comrehensive maintainability program is needed to improve operational availability, optimize logistic support infrastructure, reduce lifecycle cost, and provide data essential for project management.

Why Maintainability Engineering?
Major Interfaces

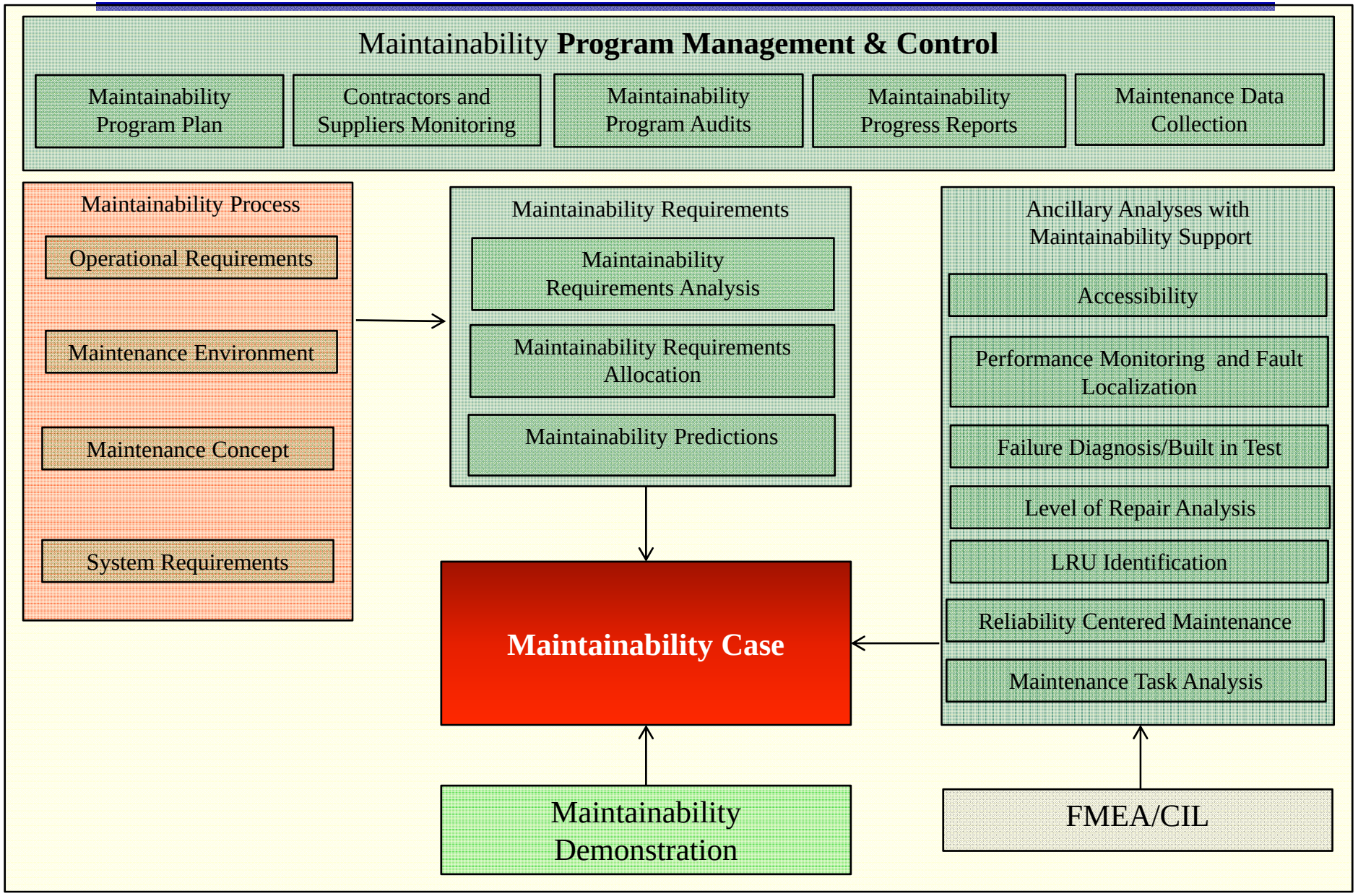
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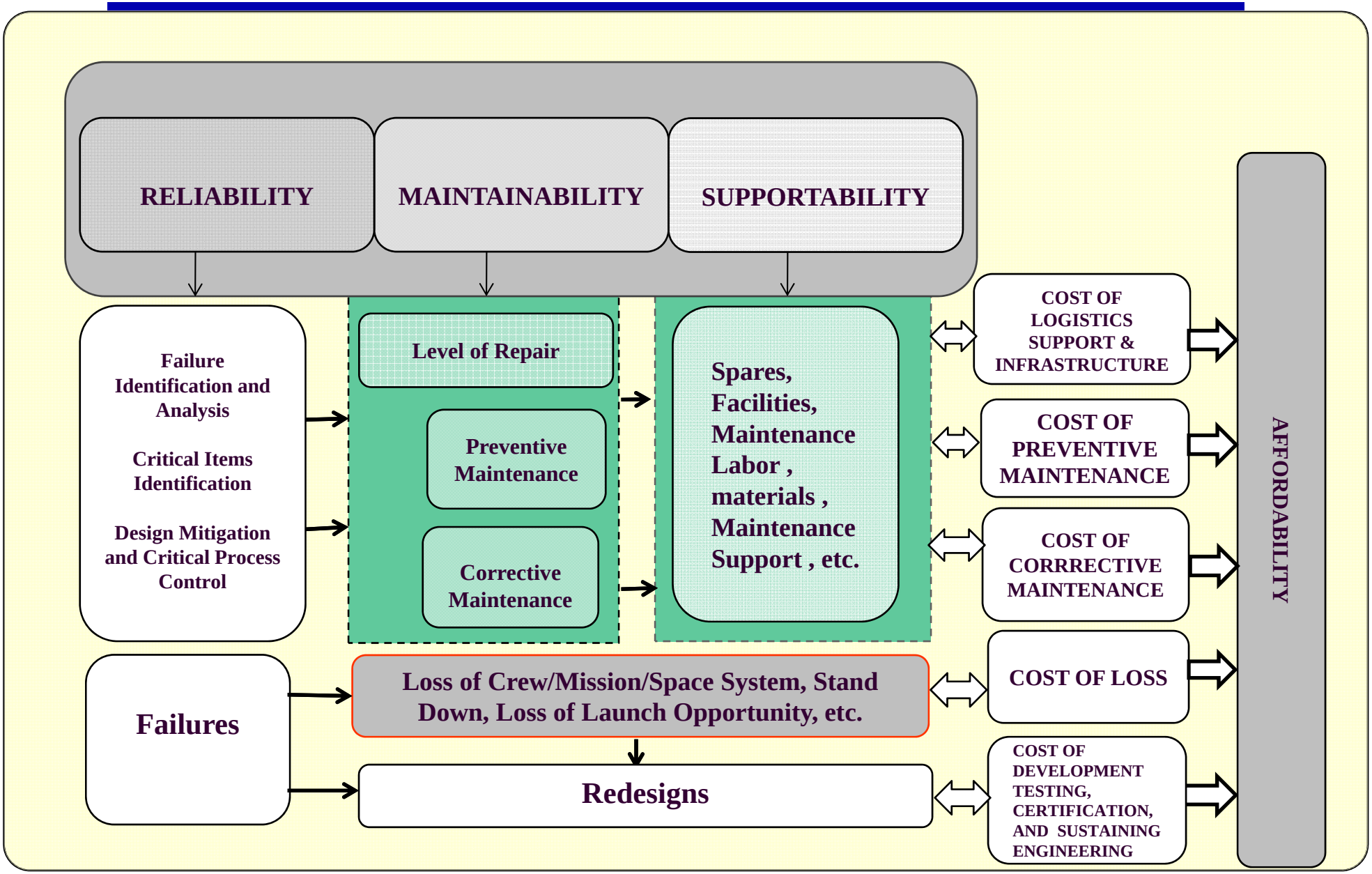


Maintainability as a figure of merit is: The probability that a product can be restored to an operable state under specified conditions and time.

The Maintainability Case

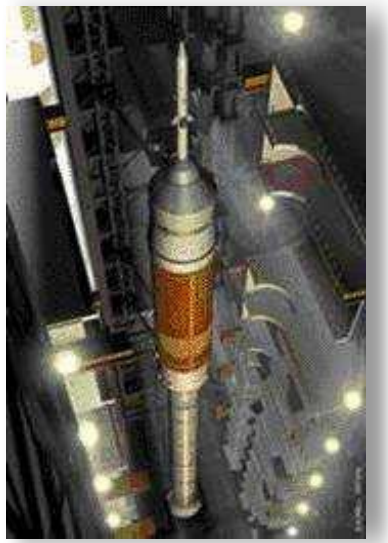


R&M Relationship to Safety and Affordability

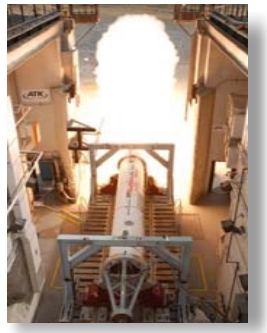


Total Cost of Ownership

- Initial purchase price, cost of design, development, assembly, integration, test, and checkout
- Scheduled maintenance costs
- Salvage values
- Unscheduled maintenance costs
- Cost of lost operations – time "making money"
- Indirect time of unscheduled maintenance

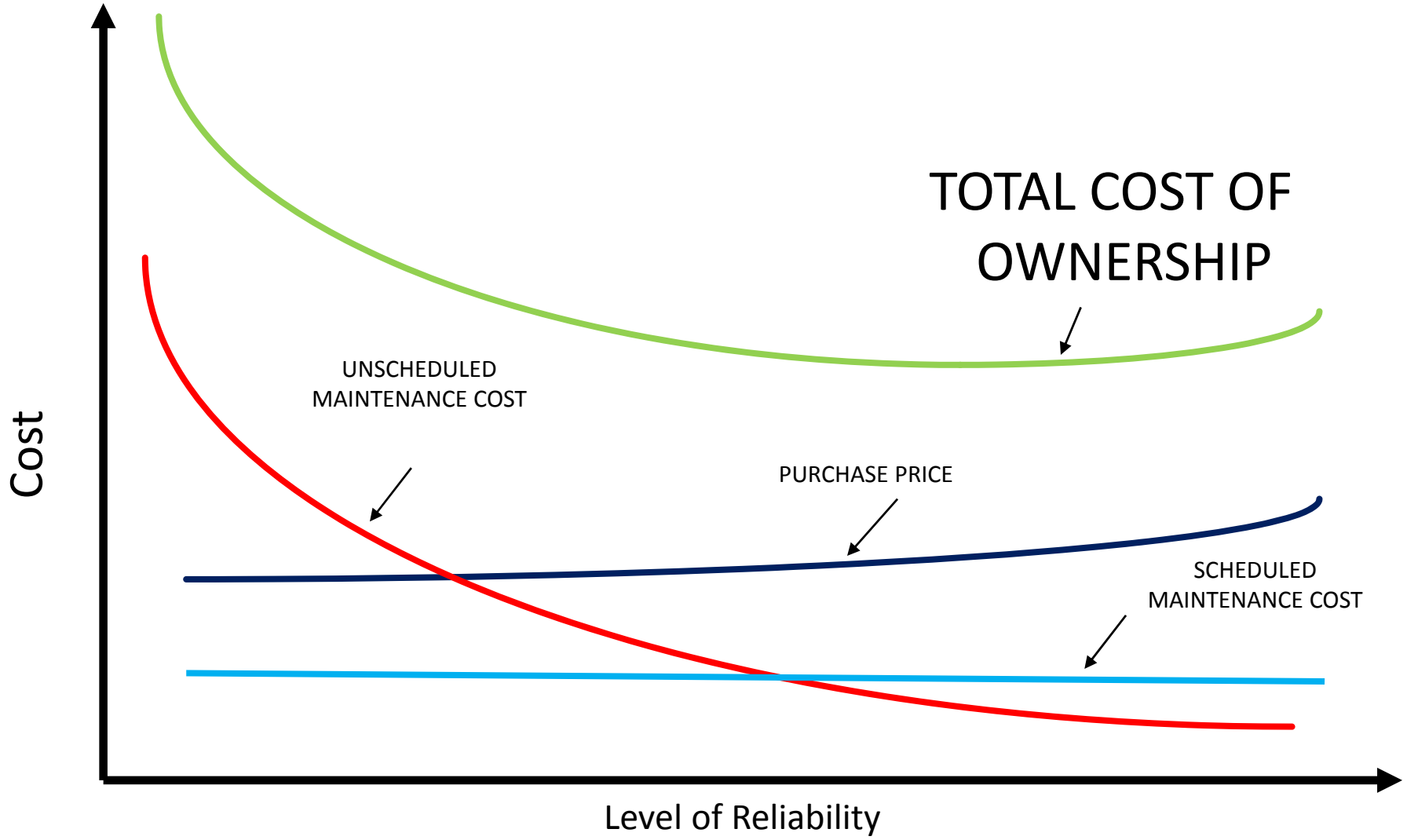








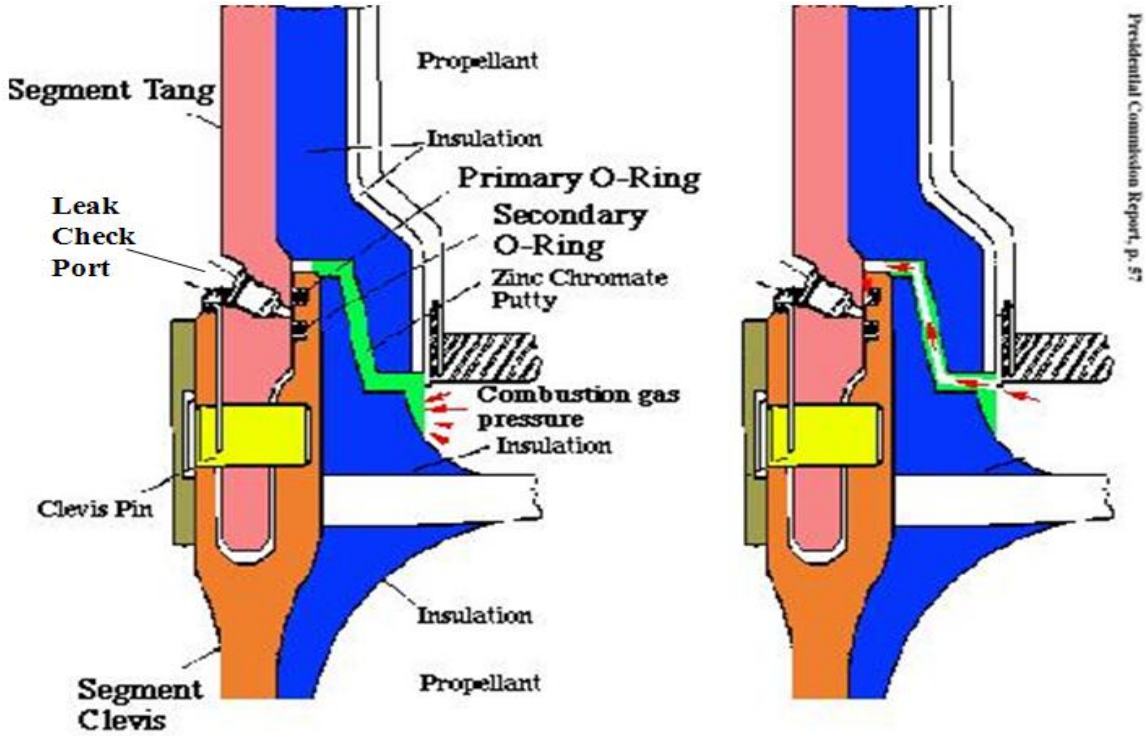
Total Cost of Ownership



Shuttle Lessons Learned
The Challenger Case

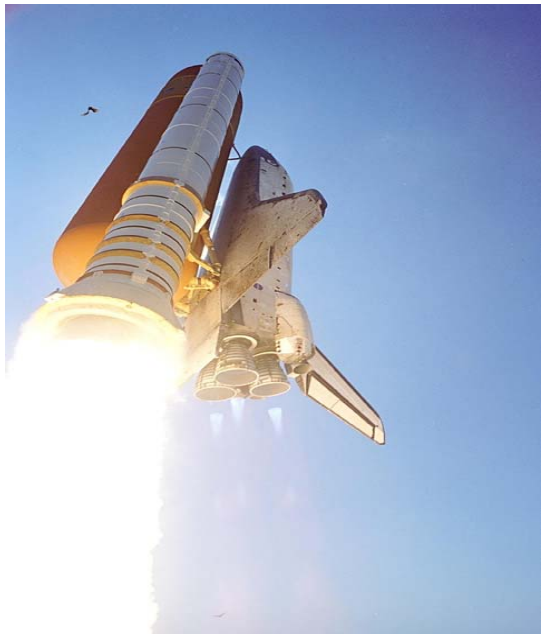
- **Causes and Contributing Factors**
 - The zinc chromate putty frequently failed and permitted the gas to erode the primary O-rings.
 - The particular material used in the manufacture of the shuttle O-rings was the wrong material to use at low temperatures.
 - Elastomers become brittle at low temperatures.

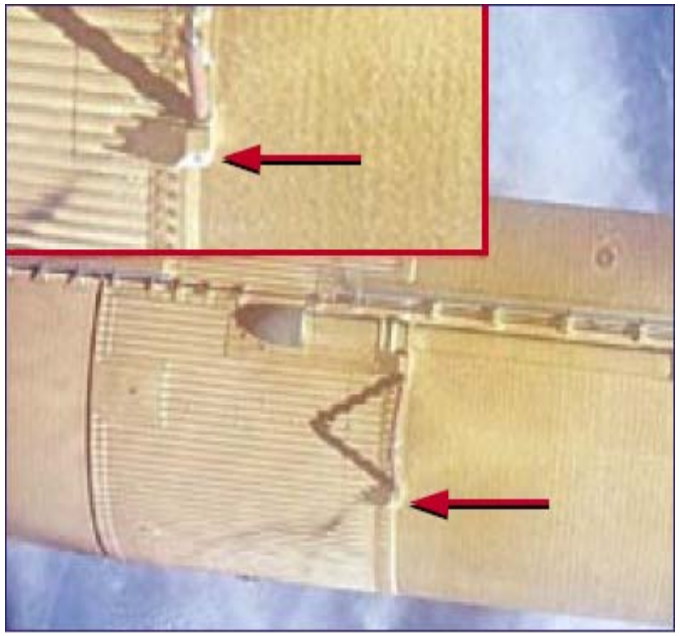




NASA Lessons Learned
The Columbia Case

- **Causes and Contributing Factors**
 - Breach in the Thermal Protection System caused by the left bipod ramp insulation foam striking the left wing leading edge.
 - There were large gaps in NASA's knowledge about the foam.
 - cryopumping and cryoingestion, were experienced during tanking, launch, and ascent.
 - Dissections of foam revealed subsurface flaws and defects as contributing to the loss of foam.





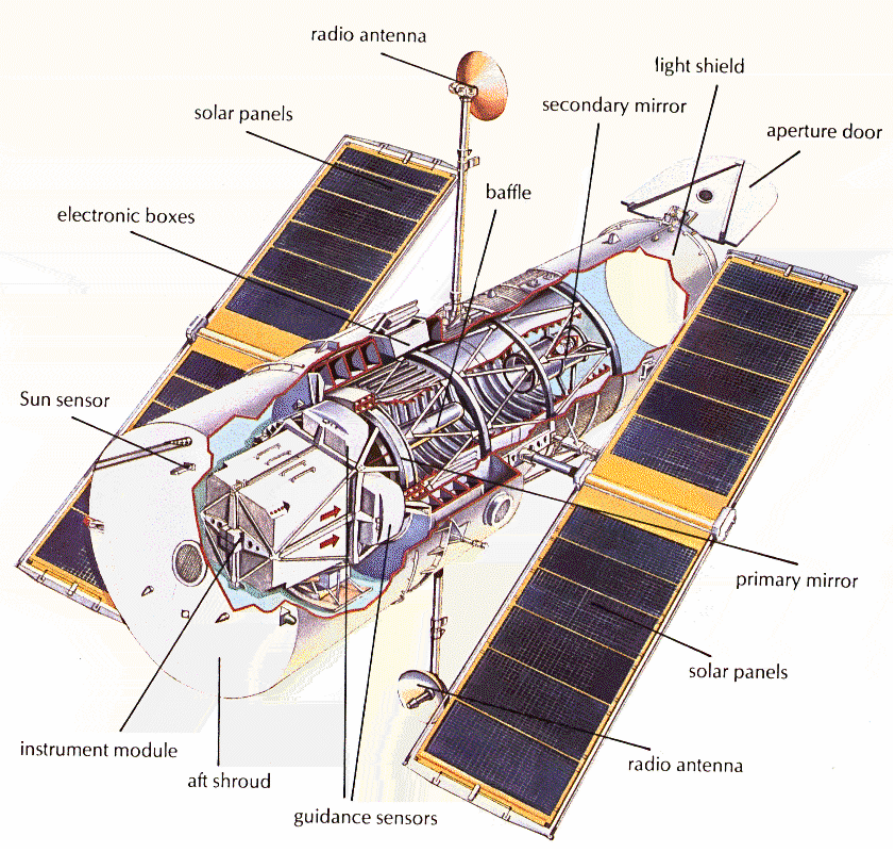


NASA Lessons Learned

The Hubble Space Telescope Success Story

Implementation of maintainability principles can reduce risk by increasing operational availability and reducing lifecycle costs.

- Enhanced System Readiness/Availability
- Reduced Downtime
- Supportable Systems
- Ease of Troubleshooting and Repair
- System Growth Opportunities
- Hardware/Software Modifications
- Interchangeability
- Modular Designs
- Decreased Storage Considerations
- Reduced Maintenance Manpower
- Reduced Operational Costs
- Compatibility with other Programs
- Reduced Management Overhead



Hubble Space Telescope was designed for Maintainability and Serviceability. Launched in 1990 it is still functioning today.

Concluding Remarks

- Lessons learned from the Challenger and Columbia accident clearly demonstrate the high cost of reliability in terms of human life, and redesigns, etc..
- Lessons learned from the Hubble Space Telescope clearly demonstrate the role of maintainability in building high availability and cost effective space systems.
- R&M is extremely critical to build safe, reliable, and cost effective systems.